OCR
Oxford Cambridge and RSA

GCE

Mathematics

Unit **4737**: Decision Mathematics 2

Advanced GCE

Mark Scheme for June 2016

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation in scoris	Meaning
 and	
BOD	Benefit of doubt
FT	Follow through
ISW	Ignore subsequent working
M0 M1 ,	Method mark awarded 0, 1
A0 A1 ,	Accuracy mark awarded 0, 1
B0 B1 ,	Independent mark awarded 0, 1
SC	Special case
^	Omission sign
MR	Misread

Other abbreviations in mark scheme	Meaning
M1 dep*	Method mark dependent on a previous mark, indicated by *
cao	Correct answer only
oe	Or equivalent
rot	Rounded or truncated
soi	Seen or implied
nfww	Not from wrong working

1. Here are the subject specific instructions for this question paper

a Annotations should be used whenever appropriate during your marking.

The A, M and B annotations must be used on your standardisation scripts for responses that are not awarded either 0 or full marks. It is vital that you annotate standardisation scripts fully to show how the marks have been awarded.

For subsequent marking you must make it clear how you have arrived at the mark you have awarded.

b An element of professional judgement is required in the marking of any written paper. Remember that the mark scheme is designed to assist in marking incorrect solutions. Correct *solutions* leading to correct answers are awarded full marks but work must not be judged on the answer alone, and answers that are given in the question, especially, must be validly obtained; key steps in the working must always be looked at and anything unfamiliar must be investigated thoroughly.

Correct but unfamiliar or unexpected methods are often signalled by a correct result following an *apparently* incorrect method. Such work must be carefully assessed. When a candidate adopts a method which does not correspond to the mark scheme, award marks according to the spirit of the basic scheme; if you are in any doubt whatsoever (especially if several marks or candidates are involved) you should contact your Team Leader.

c The following types of marks are available.

M
A suitable method has been selected and *applied* in a manner which shows that the method is essentially understood. Method marks are not usually lost for numerical errors, algebraic slips or errors in units. However, it is not usually sufficient for a candidate just to indicate an intention of using some method or just to quote a formula; the formula or idea must be applied to the specific problem in hand, eg by substituting the relevant quantities into the formula. In some cases the nature of the errors allowed for the award of an M mark may be specified.

A
Accuracy mark, awarded for a correct answer or intermediate step correctly obtained. Accuracy marks cannot be given unless the associated Method mark is earned (or implied). Therefore M0 A1 cannot ever be awarded.

B
Mark for a correct result or statement independent of Method marks.

Unless otherwise indicated, marks once gained cannot subsequently be lost, eg wrong working following a correct form of answer is ignored. Sometimes this is reinforced in the mark scheme by the abbreviation isw. However, this would not apply to a case where a candidate passes through the correct answer as part of a wrong argument.

d When a part of a question has two or more 'method' steps, the M marks are in principle independent unless the scheme specifically says otherwise; and similarly where there are several B marks allocated. (The notation 'dep *' is used to indicate that a particular mark is dependent on an earlier, asterisked, mark in the scheme.) Of course, in practice it may happen that when a candidate has once gone wrong in a part of a question, the work from there on is worthless so that no more marks can sensibly be given. On the other hand, when two or more steps are successfully run together by the candidate, the earlier marks are implied and full credit must be given.

e The abbreviation ft implies that the A or B mark indicated is allowed for work correctly following on from previously incorrect results. Otherwise, A and B marks are given for correct work only — differences in notation are of course permitted. A (accuracy) marks are not given for answers obtained from incorrect working. When A or B marks are awarded for work at an intermediate stage of a solution, there may be various alternatives that are equally acceptable. In such cases, exactly what is acceptable will be detailed in the mark scheme rationale. If this is not the case please consult your Team Leader.

Sometimes the answer to one part of a question is used in a later part of the same question. In this case, A marks will often be 'follow through'. In such cases you must ensure that you refer back to the answer of the previous part question even if this is not shown within the image zone. You may find it easier to mark follow through questions candidate-by-candidate rather than question-by-question.

f Wrong or missing units in an answer should not lead to the loss of a mark unless the scheme specifically indicates otherwise. Candidates are expected to give numerical answers to an appropriate degree of accuracy, with 3 significant figures often being the norm. Small variations in the degree of accuracy to which an answer is given (e.g. 2 or 4 significant figures where 3 is expected) should not normally be penalised, while answers which are grossly over- or under-specified should normally result in the loss of a mark. The situation regarding any particular cases where the accuracy of the answer may be a marking issue should be detailed in the mark scheme rationale. If in doubt, contact your Team Leader.

g Rules for replaced work

If a candidate attempts a question more than once, and indicates which attempt he/she wishes to be marked, then examiners should do as the candidate requests.

If there are two or more attempts at a question which have not been crossed out, examiners should mark what appears to be the last (complete) attempt and ignore the others.

NB Follow these maths-specific instructions rather than those in the assessor handbook.

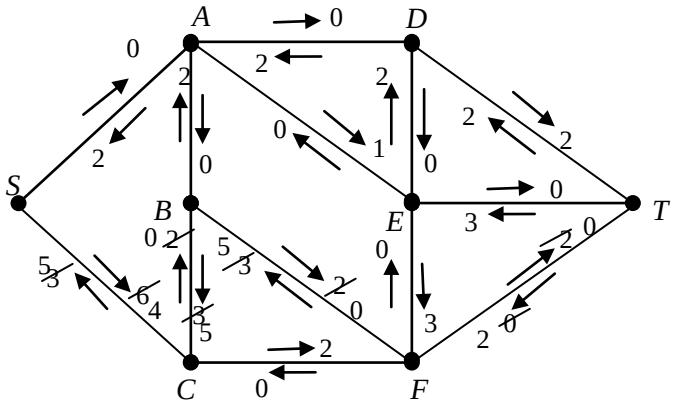
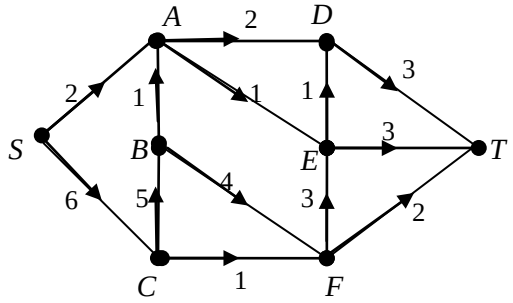
h For a *genuine* misreading (of numbers or symbols) which is such that the object and the difficulty of the question remain unaltered, mark according to the scheme but following through from the candidate's data. A penalty is then applied; 1 mark is generally appropriate, though this may differ for some units. This is achieved by withholding one A mark in the question.

Note that a miscopy of the candidate's own working is not a misread but an accuracy error.

2. Here is the mark scheme for this question paper.

MARK SCHEME

Question			Answer/Indicative content	Mark	Guidance
1	(i)		JF – 3 – ND – 4 1 = MA (Mar/Apr) 2 3 = JF (Jan/Feb) 4 = ND (Nov/Dec) 5 = JA (Jul/Aug) 6 = MJ (May/Jun)	M1 A1 **[2]**	Alternating path (cao), allow any unambiguous notation Must be written down not implied from diagram or from matching This incomplete matching written (cao, with unambiguous notation for months) 2 may e.g. blank, –, X, but NOT paired with SO
	(ii)		SO – 5 – JA – 2 1 = MA (Mar/Apr) 2 = JA (Jul/Aug) 3 = JF (Jan/Feb) 4 = ND (Nov/Dec) 5 = SO (Sep/Oct) 6 = MJ (May/Jun)	M1 A1 **[2]**	Alternating path, following from a valid path used in (i), allow any unambiguous notation Must be written down not implied from diagram or from matching Complete matching from their path, written with unambiguous notation for months
	(iii)		3 must pair with JF (since 3 is the only picture that is suitable for JF), so 3 cannot be paired with SO or ND. This means that 5 must pair with SO and 4 with ND 1 = MJ (May/Jun) 2 = MA (Mar/Apr) 3 = JF (Jan/Feb) 4 = ND (Nov/Dec) 5 = SO (Sep/Oct) 6 = JA (Jul/Aug)	M1 A1 B1 ft **[3]**	Identifying 3 = JF Stating that this leads to 5 = SO and 4 = ND (need some words here, or ⇒, and must follow from 3 = JF first) A correct complete matching that is not the same as the one credited in part (ii) (i.e. this matching or the one that is given in (ii) above, if that was not credited in (ii)) If more than one matching given, need both correct and no extras

Question			Answer/Indicative content	Mark	Guidance
2	(i)		*FT* has capacity 2 litres per second *DT* has capacity 4 litres per second Value of cut = 4+3+2 = 9 litres per second	B1 B1 M1 A1 **[4]**	*FT* = 2 (cao) *DT* = 4 (cao) Ignore any extra arc capacities if given 4+3+2 or (numerically) their *DT* capacity+3+their *FT* capacity (soi) 9 (cao) (units may be implied)
	(ii)	(a)		M1 A1	Updating route *SCBFT* Correct updating of *SCBFT* (May show a second updating, in which case the first updating must be able to be seen)
		(b)	Flow augmenting route *S-C-F-B-A-E-D-T* Flow = 1	M1 A1 **[4]**	*S C F B A E D T* (cao) 1 (cao)
	(iii)		 Cut that separates {*S*, *A*, *B*, *C*, *F*} from {*D*, *E*, *T*}	B1 B1 **[2]**	Valid flow of 8 litres per second SC: With *CBF* -1 and *CF* +1 and/or with *EDT* +1, *ET* -1 (i.e. allow *CB* = 4, *BF* = 3, *CF* = 2 and/or *ED* = 2, *DT* = 4, *ET* = 2) Cut through arcs *AD*, *AE*, *EF*, *FT* (may be drawn on diagram, provided it is obvious which cut is the answer) (cao)

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>3</td><td>(i)</td><td></td><td>Add a dummy column of equal non-negative values
<table>
<tr><td>e.g.</td><td>L</td><td>S</td><td>T</td><td>X</td><td></td></tr>
<tr><td>A</td><td>86</td><td>88</td><td>90</td><td>100</td><td>(-86)</td></tr>
<tr><td>B</td><td>92</td><td>94</td><td>95</td><td>100</td><td>(-92)</td></tr>
<tr><td>C</td><td>88</td><td>92</td><td>94</td><td>100</td><td>(-88)</td></tr>
<tr><td>D</td><td>98</td><td>100</td><td>98</td><td>100</td><td>(-98)</td></tr>
</table>
Rows reduced
<table>
<tr><td>e.g.</td><td>L</td><td>S</td><td>T</td><td>X</td></tr>
<tr><td>A</td><td>0</td><td>2</td><td>4</td><td>14</td></tr>
<tr><td>B</td><td>0</td><td>2</td><td>3</td><td>8</td></tr>
<tr><td>C</td><td>0</td><td>4</td><td>6</td><td>12</td></tr>
<tr><td>D</td><td>0</td><td>2</td><td>0</td><td>2</td></tr>
<tr><td></td><td>(-0)</td><td>(-2)</td><td>(-0)</td><td>(-2)</td></tr>
</table>
Columns reduced
<table>
<tr><td>e.g.</td><td>L</td><td>S</td><td>T</td><td>X</td></tr>
<tr><td>A</td><td>0</td><td>0</td><td>4</td><td>12</td></tr>
<tr><td>B</td><td>0</td><td>0</td><td>3</td><td>6</td></tr>
<tr><td>C</td><td>0</td><td>2</td><td>6</td><td>10</td></tr>
<tr><td>D</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table></td><td>B1

M1

A1

B1

B1ft
[5]</td><td>Making a square matrix by adding a column of equal values (even if values are zero)
[Dummy column is labelled as X here, but it may have any label]
Deleting row D gets B0 but can get other marks

Each row reduced by its min value (showing the numbers to be subtracted or an attempt at doing the reduction)
Their rows reduced correctly to give all 0’s in column L, even if not a square matrix.
[This mark is not available if original dummy values were all 0.]
Each column of their row reduced matrix has been correctly reduced by its min value

Columns reduced first ⇒ B1 for showing that each column has been reduced by its min value and SC1 for having all 0’s in row A and column X (so max for (i) = 4 marks)
All values subtracted from e.g. 100 and then reduced ⇒ B1 only (so max for (i) = 3 marks)

Crossing out 0’s using min number of lines for their reduced cost matrix (even if not square)</td></tr>
<tr><td></td><td>(ii)</td><td></td><td>Augment by 3
<table>
<tr><td></td><td>L</td><td>S</td><td>T</td><td>X</td></tr>
<tr><td>A</td><td>0</td><td>0</td><td>1</td><td>9</td></tr>
<tr><td>B</td><td>0</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>C</td><td>0</td><td>2</td><td>3</td><td>7</td></tr>
<tr><td>D</td><td>3</td><td>3</td><td>0</td><td>0</td></tr>
</table>
A = S B = T C = L
Total cost = £88+88+95 = £271</td><td>M1

A1

B1
B1
[4]</td><td>Substantially correct attempt to augment by minimum uncovered element (must see at least one cell ‘of each type’ augmented correctly) (M0 if 4 lines used in (i))
This 4×4 matrix achieved in a single augmentation (cao)

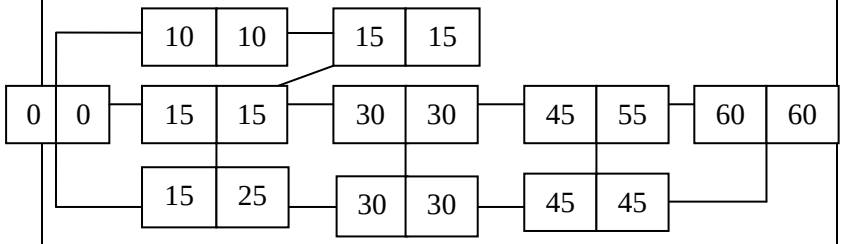
Correct allocation (written). Ignore D = X if included.
271 (cao as final answer, not ft) (units not necessary)</td></tr>
<tr><td></td><td>(iii)</td><td></td><td>B = T and C = S
Cost = £187
271 – 1 – 187 = 83
Amir should cost operating the lighting at £83</td><td>B1
B1 ft
M1
A1
[4]</td><td>B = T, C = S (cao) (may also write A = L)
187 seen, or 95 and 92 seen, (or ft their allocation for S and T)
Their (271 – 1) – their (92 + 95) soi
83 (cao) not from wrong working</td></tr>
</table>

Question			Answer/Indicative content	Mark	Guidance
4			Candidates may use icons (✂, 🗋, ●) or initial letters (S, P, R) for scissors, paper, rock at any stage in their answers		
	(i)		For example, when Rowan plays scissors and Colin plays paper, Rowan wins 1 but Colin loses 2, the sum of these is not zero. Rowan wins: S: 0, 1, -1; P: -2, 0, 2; R: 2, -2, 0 Colin wins: S: 0, -2, 2; P: 1, 0, -2; R: -1, 2, 0	B1 **[1]**	Identifying a case where one player chooses scissors and the other chooses either paper or rock and showing that what one player wins does not equal what the other player loses. (Need not say that sum is not zero) [But not for misunderstanding the tables, e.g. saying that when R plays S and C plays P Rowan wins 1 and loses 2]
	(ii)		Rowan plays — Minimum points scissors -1 paper -2 rock -2 Maximin strategy is to play scissors	M1 A1 **[2]**	scissors -1; paper and rock -2 Must be seen, not implied Scissors (or S, but strategy must be written)
	(iii)		Colin plays — Rowan expects to win scissors $-2q + 2(1 - q - p) = 2 - 2p - 4q$ paper $p - 2(1 - q - p) = 3p + 2q - 2$ rock $-p + 2q = 2q - p$	B1 B1 B1 **[3]**	$-2p - 4q + 2$ (or equivalent, but must be simplified) $3p + 2q - 2$ (or equivalent, but must be simplified) $-p + 2q$ (or equivalent, but must be simplified)
	(iv)		$-2p - 4q + 2 = 3p + 2q - 2$ (so $5p + 6q = 4$) Or $-2p - 4q + 2 = -p + 2q$ (so $p + 6q = 2$) Or $3p + 2q - 2 = -p + 2q$ (so $4p = 2$ so $p = 0.5$) $0.5 + 6q = 2$ so $q = 0.25$ $2.5 = 6q = 4$ Rowan plays — Probability scissors 0.5 paper 0.25 rock 0.25	M1 A1 B1 B1 **[4]**	Showing setting any two of their expressions equal to one another [watch out for e.g. $-p + 2q = 0 \Rightarrow p = 2q$ or $p + q = 1$] Valid algebraic manipulation of three correct expressions leading to a correct value for p or q [Again, watch out for, e.g. $p = 2q$ from $-p + 2q = 0$ assumed] $p = 0.5$ and $q = 0.25$ P(scissors) = 0.5, P(paper) = 0.25, P(rock) = 0.25 in table

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>5</td><td>(i)</td><td></td><td>F and H</td><td>M1
A1
[2]</td><td>Either F or H in a list of no more than four activities
Both F and H (become critical, and no others). Allow C, F and H</td></tr>
<tr><td></td><td>(ii)</td><td></td><td>
<table>
<tr><th>Activity</th><th>Preceded by</th></tr>
<tr><td>A</td><td>-</td></tr>
<tr><td>B</td><td>-</td></tr>
<tr><td>C</td><td>-</td></tr>
<tr><td>D</td><td>A</td></tr>
<tr><td>E</td><td>B, D</td></tr>
<tr><td>F</td><td>B, C, D</td></tr>
</table>
<table>
<tr><th>Activity</th><th>Preceded by</th></tr>
<tr><td>G</td><td>E</td></tr>
<tr><td>H</td><td>E, F</td></tr>
<tr><td>I</td><td>G, H</td></tr>
<tr><td>J</td><td>H</td></tr>
</table>
</td><td>B1

B1

[2]</td><td>Immediate predecessors correct (with no extras) for A to F
Immediate predecessors for A, B, C may be left blank

Immediate predecessors correct (with no extras) for G to J</td></tr>
<tr><td></td><td>(iii)</td><td></td><td> 

Minimum project completion time = 60 minutes (or 1 hour)
Critical activities A, B, D, E, H, J</td><td>M1
A1

M1
A1

B1
B1
[6]</td><td>Forward pass with at most one independent error
Forward pass correct

Backward pass with at most one independent error
Backward pass correct (including 0 and 60)

60 (units not necessary) or 1 hour (with units), (cao, not ft)
A, B, D, E, H, J (cao, not ft)</td></tr>
<tr><td></td><td>(iv)</td><td></td><td>eg
<table>
<tr><td>Person 1</td><td>A</td><td>A</td><td>D</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Person 2</td><td>B</td><td>B</td><td>B</td><td>E</td><td>E</td><td>E</td><td>H</td><td>H</td><td>H</td><td>J</td><td>J</td><td>J</td><td></td></tr>
<tr><td>Person 3</td><td>C</td><td>C</td><td></td><td>F</td><td></td><td></td><td>G</td><td>G</td><td></td><td>I</td><td></td><td></td><td></td></tr>
</table>
</td><td>B1
B1

[2]</td><td>One person per activity (but it does not matter who does what)
Start times and durations correct for critical activities
Start times and durations correct for non-critical activities</td></tr>
<tr><td></td><td>(v)</td><td></td><td>eg
<table>
<tr><td>Person 1</td><td>A</td><td>A</td><td>D</td><td>C</td><td>C</td><td>F</td><td>G</td><td>G</td><td></td><td>I</td><td></td><td></td><td></td></tr>
<tr><td>Person 2</td><td>B</td><td>B</td><td>B</td><td>E</td><td>E</td><td>E</td><td>H</td><td>H</td><td>H</td><td>J</td><td>J</td><td>J</td><td></td></tr>
</table>
</td><td>B1
B1
[2]</td><td>One person per activity (but it does not matter who does what)
Start times and durations correct for critical activities
Valid start times and correct durations for non-critical activities</td></tr>
<tr><td></td><td>(vi)</td><td></td><td>Would need to reduce B as well
So cheapest method is to reduce H and J at a total cost of £1000</td><td>B1
B1
[2]</td><td>If A is reduced then B must be reduced as well
H, J and 1000 (cao) (seen, not implied)</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>6</td><td>(i)</td><td></td><td>
<table>
<tr><th>Stage</th><th>State</th><th>Action</th><th>Working</th><th>Suboptimal maximum</th></tr>
<tr><td rowspan="2">3</td><td>0</td><td>0</td><td>1</td><td>1</td></tr>
<tr><td>1</td><td>0</td><td>2</td><td>2</td></tr>
<tr><td rowspan="4">2</td><td rowspan="2">0</td><td>0</td><td>1 + 1 = 2</td><td rowspan="2"></td></tr>
<tr><td>1</td><td>1 + 2 = 3</td><td>3</td></tr>
<tr><td rowspan="2">1</td><td>0</td><td>3 + 1 = 4</td><td>4</td></tr>
<tr><td>1</td><td>1 + 2 = 3</td><td></td></tr>
<tr><td rowspan="4">1</td><td rowspan="2">0</td><td>0</td><td>1 + 3 = 4</td><td rowspan="2"></td></tr>
<tr><td>1</td><td>0 + 4 = 4</td><td>4</td></tr>
<tr><td rowspan="2">1</td><td>0</td><td>0 + 3 = 3</td><td rowspan="2"></td></tr>
<tr><td>1</td><td>1 + 4 = 5</td><td>5</td></tr>
<tr><td rowspan="2">0</td><td rowspan="2">0</td><td>0</td><td>2 + 4 = 6</td><td rowspan="2"></td></tr>
<tr><td>1</td><td>2 + 5 = 7</td><td>7</td></tr>
</table>
Maximum = 7
Route (0; 0) – (1; 1) – (2; 1) – (3; 0) – (4; 0)
</td><td>B1

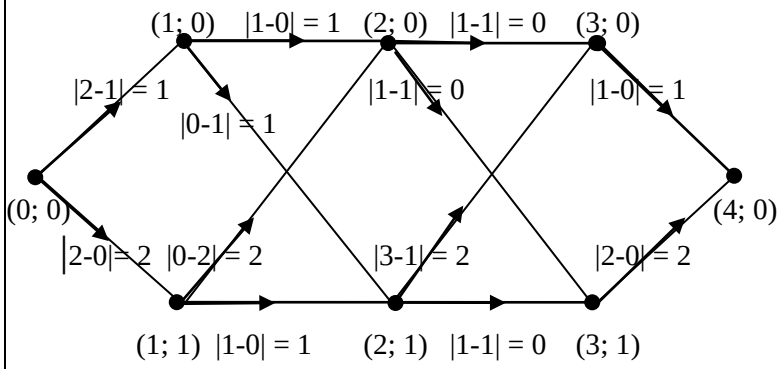
M1
A1

B1

B1
B1
[6]</td><td>Transferring suboptimal values correctly to stage 1
(3, 4, 3, 4 as second element inside brackets)

Calculating (their) totals correctly at stage 1 (4, 4, 3, 5)
Calculating (their) suboptimal maximum values correctly at stage 1
(4, 5) - need not be lined up with row, provided in correct zone

Stage 0 all correct (cao)

7 (cao)
This route, or in reverse, including (0; 0) and (4; 0)</td></tr>
<tr><td></td><td>(ii)</td><td></td><td>0 + 0 + 1 + 0 = 1</td><td>B1
[1]</td><td>1 (follow through their route from part (i) if possible)</td></tr>
<tr><td></td><td>(iii)</td><td></td><td> 
</td><td>B1

M1

A1

[3]</td><td>Structure and vertex labels all correct, arcs must be directed
Accept commas used instead of semicolons

Arc weights correct for stages 0 and 3
1, 2 from (0; 0) and 1, 2 into (4; 0) (correctly placed)

All arc weights correct
1, 1 and 2, 1 for stage 1; 0, 0 and 2, 0 for stage 2 (correctly placed)

Need not see working for arc weights</td></tr>
</table>

Question	Answer/Indicative content	Mark	Guidance
(iv)			

Stage	State	Action	Working	Suboptimal minimax
3	0	0	1	1
	1	0	2	2
2	0	0	max(0, 1) = 1	1
		1	max(0, 2) = 2	
	1	0	max(2, 1) = 2	**2**
		1	max(0, 2) = 2	
1	0	0	max(1, 1) = 1	**1**
		1	max(1, 2) = 2	
	1	0	max(2, 1) = 2	**2**
		1	max(1, 2) = 2	
0	0	0	max(1, 1) = 1	**1**
		1	max(2, 2) = 2	

	B1ft	Transferring their absolute differences correctly (ft or correct)
	M1	Working values for stage 2 calculated as the maximum of their absolute difference and appropriate suboptimal value from stage 3
	A1	Suboptimal minimax for stage 2 calculated as the minimum of their working (max) values for each state and indicated
	M1	Working column <u>and</u> suboptimal column correct for stage 1, following through their (written) absolute differences and their suboptimal values from stage 2
	A1	Working column <u>and</u> suboptimal column correct for stage 0. Following through their (written) absolute differences and their suboptimal values from stage 1
Route (0; 0) – (1; 0) – (2; 0) – (3; 0) – (4; 0)	B1	This route, or in reverse, (cao)
	[6]	

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